STUDIES IN THE SURGICAL ANATOMY OF THE SMALL INTESTINE AND ITS MESENTERY.*

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THE "Studies" herewith reported concern that part of the small intestine which extends from the end of the duodenum to the ileocæcal valve, and which is known to anatomists as the "jejuno-ileum."

About two years ago I began certain investigations on the cadaver for the purpose of determining whether, when a loop of small intestine appears in an abdominal wound, there is any means by which the surgeon may get an approximate idea as to the part of the intestine which the loop occupies. After a careful examination of the gut and its mesentery in a large number of subjects to see if there were any points about the intestine or its mesentery which might serve to differentiate one part of the tube from the rest of it, a series of tests was conducted through various abdominal wounds on the cadaver for the purpose of finding out with what degree of success this information could be practically applied. To this process I gave the name, "Intestinal Localization." The results were sufficiently gratifying to justify me in thinking that the process was a practical one, and that it might be useful on the living subject. I therefore reported the results of these investigations to the American Surgical Association at the Annual Meeting, May, 1903.† While I was working on the subject of intestinal

* The Mütter Lecture for 1904, delivered at the College of Physicians of Philadelphia, December 2, 1904.

† They were published in the Transactions of the Association, and also in the ANNALS OF SURGERY for October, 1903. Since making this report, I have had good reason to believe, both from my own experience and from that of other surgeons who have kindly communicated their results to me, that the method may be of great use on the living subject whenever

localization, I noted incidentally certain other directions in which investigations might be made with a fair promise of good results. I therefore conducted a new series of studies on the cadaver, this time, however, more in reference to such points of general surgical interest as might develop in the course of the work than to the subject of intestinal localization. In these studies * I was most efficiently assisted by Drs. W. E. Faulkner, D. D. Scannell, and W. C. Howe, as well as by several other physicians, and it gives me pleasure to acknowledge here my indebtedness to them.

The studies, which are necessarily somewhat fragmentary, are embraced under the following headings:

1. The length of the intestine, as measured from the end of the duodenum to the ileocæcal valve.

2. The length of the mesentery, as measured from the mesenteric root to different parts of the intestine.

3. The distance to which the different loops of the intestine may be drawn downward in the median line towards the pubes; results of tests.

4. Relative functional value of jejunum and ileum; resection of portions of ileum.

5. Demonstrations of the real shape of the mesentery.

6. Disposition of the mesentery in the abdominal cavity.

7. *The pelvic fold of the mesentery;* how to palpate it: its use as a landmark.

8. How to find the lower end of the ileum through an abdominal wound.

9. Influence of the mesentery on the course of the intestine:

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it is desirable for the surgeon to know quickly what part of the intestinal canal a given loop occupies.

* Of the material used in this work, a part belonged to the Surgical Department of the Harvard Medical School; the remainder was kindly furnished by the Anatomical Department of that institution, and by the Pathological Department of the Boston City and of the Long Island Hospitals. I wish here to thank Drs. Thomas Dwight, F. B. Mallory, and G. B. Magrath, who represent the last three departments mentioned, for their courtesy in allowing me the use of it.

(*a*) Influence of the mesentery on short segments of intestine.

(*b*) Influence of the mesentery on longer segments of intestine.

(*c*) Kinks in the intestine.

10. Course of the intestine as affected by conditions within the abdomen.

11. Distention of intestines; experiments in the introduction and removal of air and water.

12. The passing of instruments into an enterostomy opening.

13. The determination of the real direction in a loop of bowel.

14. Conclusions.

The drawings were made from specimens, or from photographs, or from both.

THE LENGTH OF THE JEJUNO-ILEUM.

In the course of these investigations I made a number of measurements of the length of the jejuno-ileum, but, as similar measurements have already been made by a number of other investigators, I shall dismiss the subject in a few words. In thirty-one adult cadavers, of both sexes and of different nationalities, where the intestine was measured *in situ*, the average length was a little less than 23 feet (7.01 metres), the shortest being 14 feet (4.27 metres) and the longest 33 feet 10 inches (10.31 metres). All these measurements, with the exception of two, or possibly three, at the very beginning of the work, were made with a tape-measure, the intestine being *in situ*, and the abdominal cavity freely laid open from ensiform cartilage to pubes.*

Remarks.—Because of the fact that a long tube like the intestine, which can be so easily stretched, does not readily

* In twelve other cadavers, also of both sexes and of different nationalities, where the intestines were kindly measured for me by my colleagues and others, the same method being used, the average length was found to be a little less than that given above.

lend itself to so exact a process as that of accurate measurement, and also because in the process of measurement so many other sources of error may enter, I am of the opinion that statements made in text-books and elsewhere aim at an exactness which the facts do not justify. The average length of the small intestine of the adult (measured from the end of the duodenum to the ileocæcal valve) is probably somewhere between 21 and 23 feet (between 6 and 7 metres). The fact that the intestine varies greatly in length in different individuals, interesting as it may be, does not, however, especially concern the surgeon, except that a long intestine means more loops and a more complicated arrangement of coils, and that from such an intestine greater lengths of ileum may be resected without danger of interfering with nutrition than from a shorter one.

In connection with this subject, it is well to bear in mind, where the intestine is measured *in situ*, the great difference between the length of the gut when the measurement is made along its free border as compared with that made along its attached or mesenteric border. Thus, in one case in my series, while the gut along its free border measured about 20 feet (6.10 metres), it measured only 15 feet (4.57 metres) along its mesenteric border, showing a difference of 5 feet (1.50 + metres) between the two measurements. The free border of the gut is therefore much longer than the mesenteric border, and the free border may therefore appropriately be called the "long side" of the gut and the mesenteric border its "short side."

THE LENGTH OF THE MESENTERY.

On account of the usefulness in a general way of knowing the distance to which the various parts of the intestinal tube may reach in different directions within and without the abdominal cavity, I have measured the length of the mesentery at different distances down the intestine. The measurements were taken from the attachment of the mesentery on the pos-

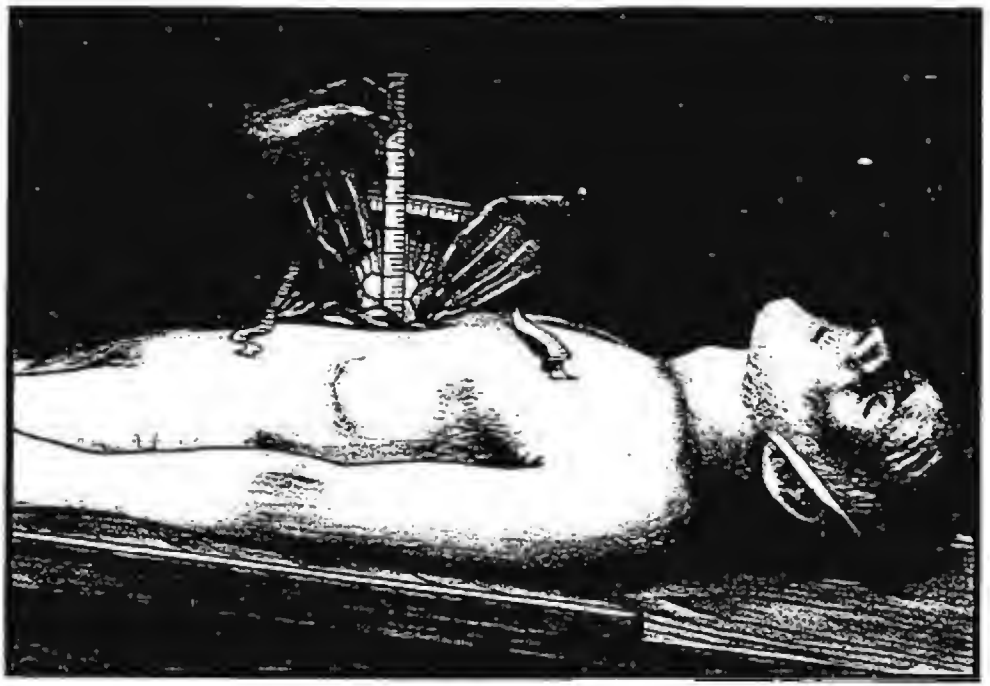

FIG. 1.—Showing the method for determining the length of the mesentery at different points along the intestine (usually at every foot) from the end of the duodenum to the ileocæcal valve. One hand of the assistant is shown. His other hand held the ruler in exact contact with the mesenteric root, but, for the sake of simplicity, this hand was omitted in the illustration. (Drawn from the cadaver and from a photograph.)

terior abdominal wall to the edge of the mesentery where it is attached to the intestine. The method I employed for taking these measurements—and this was done on twenty cadavers—is shown in the accompanying illustration (Fig. 1).

Results.—The results of these measurements show, as far at least as we can judge from twenty cases, that:

(1) As a rule, the length of the mesentery gradually increases from the end of the duodenum up to the fourth or fifth foot of the gut, at which point it usually reaches its maximum. Occasionally it reaches its full length even earlier. Opposite the lower end of the gut, the length of the mesentery diminishes again, rather more abruptly than is the case opposite the upper end of the canal.

(2) Throwing out of consideration the upper and lower extremities of the mesentery, that structure varies, as a rule, from 5 to 7 inches in length (13 to 18 centimetres), the extremes being about 4½ inches and 8 inches (11½ centimetres and 20½ centimetres).*

(3) Short mesenteries are usually short throughout and long ones usually long throughout; all, however, showing some variations in length in the course of the canal.

(4) As a rule, it may be said that the longer the intestine the longer the mesentery, and the shorter the intestine the shorter the mesentery, though there are marked exceptions to this rule.†

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*This result differs from that given by Treves, who says: "The length of the mesentery from the spine to the intestine varies in different parts of the canal; its average length may be taken as between eight and nine inches." As my own measurements show the average to vary between five and seven inches, I can explain the disagreement only on the assumption that possibly, in speaking of the length of the mesentery, Treves included the width of the gut also, for, if this were so, the two averages would more nearly agree.

†In one intestine which measured 30 feet 8 inches (9.35 metres), at only one point did the mesentery reach the length of 6 inches (15¼ centimetres); while in another intestine, which was only 14 feet long, the mesentery measured 6 inches at several points.

THE DISTANCE TO WHICH DIFFERENT LOOPS OF THE INTESTINE MAY BE DRAWN DOWNWARD IN THE MEDIAN LINE.

For the sake of determining roughly the relative mobility of the different parts of the small intestine in a downward direction, I have made a number of measurements on cadavers. These measurements rather suggest the probability that it must be unusual for a loop in the upper part of the tube to occupy a position in the lower part of the abdomen or in the pelvis. Conversely, as I have ascertained by drawing loops from the lower part of the tube upward, it is probably also unusual for one in the lower part of the tube to occupy a region high up in the abdomen. This general rule, to which, however, there may be occasional and marked exceptions, is of use in giving us a certain amount of information as to what loops we are most apt to meet through an incision in one or the other of these two regions.

Sixteen subjects in all were used, and in each subject a loop of intestine was drawn down at every foot, and the measurement taken. It was found more convenient and exact for purposes of comparison to take the measurements *upward* from the level of the pubic spine to the various loops as they were drawn downward one after another. The method used is shown in Fig. 2. The abdomen has been freely laid open from ensiform cartilage to pubes.

Results.—Summarizing the results, I find that:

(1) Taking the loops in succession, from above downward, each, as a rule, reached a little lower than the preceding one.

(2) A loop from the first foot of the jejunum could, on the average, be drawn to a point about 3 inches (7½ centimetres) above the pubes. The extremes were ½ inch (1¼ centimetres) and 4½ inches (11½ centimetres).

(3) In all but one of the subjects the pubes was reached by some part of the intestine. This usually did not occur before the tenth foot of the canal had been brought down.

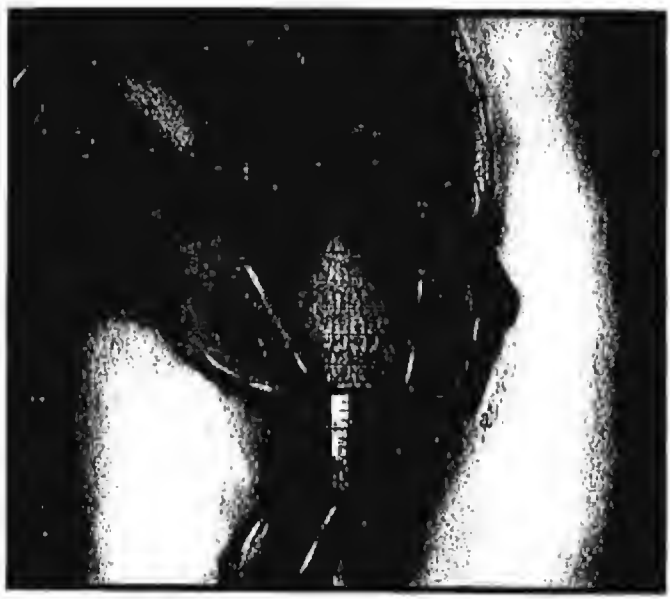


FIG. 2.—Showing the method of determining the point above the pubes to which a loop of small intestine will reach when gently drawn downward. The measurement is taken upward from the level of the spine of the pubes (a) to the free border of the intestinal loop. The dotted lines on the intestine and mesentery are arbitrary lines, indicating the levels of certain intestinal loops which do not reach so near to the pubes as does the loop shown in the illustration.

(4) As for the frequency with which the free edge of the intestine reached *below the pubes,* my measurements in these sixteen cadavers showed that in about two-thirds of the cases the free edge of some part of the gut reached a point which varied from 1 to 3 inches (2½ to 7½ centimetres) below that landmark.

RELATIVE FUNCTIONAL VALUE OF THE JEJUNUM AND ILEUM; RESECTION OF PORTIONS OF ILEUM.

One can hardly fail to be impressed with the idea that the ileum, or at least the lower part of it, is apparently of less functional value than the jejunum. When one puts a coil from the jejunum beside one from the ileum and studies these two loops and the characteristics of the attached mesentery, one is struck with what seems to be the superior arrangement, for functional activity at least, of the upper to that of the lower segment of gut. The jejunum is usually thick and muscular, is filled with large and numerous valvulæ conniventes, and is evidently supplied with a great deal of blood, since the blood-vessels of the mesentery are large and straight and possess comparatively few branches. The ileum, on the other hand, is generally thin and flabby, and its valvulæ conniventes, if indeed there are any present, are smaller and less numerous than those of the jejunum, while the small, tortuous, and frequently branching vessels of its mesentery suggest a poor blood supply and a correspondingly low degree of functional activity. Judging from these facts, and from the numerous cases in which good results have been obtained after resection of appreciable lengths of the ileum, it may be assumed that a large portion of the lower part of the small intestine may, apparently, be sacrificed without detriment to health. I know of the case of one patient, a gentleman of thirty-three years, from whose ileum about three years ago nearly 8 feet (2.44 metres) of the tube was resected, recovery resulting.* I know this gentleman

*This case was reported by George R. Harris, M.D. (of Norwich, Conn.), in the Medical Record, October 11, 1902.

personally, and I recently had a talk with him about his case. He said that he felt perfectly well,—better, in fact, than he had for years before the operation; that he was able to digest his food without discomfort; that he was no longer troubled with constipation and headache, which had formerly annoyed him; that he had lost no weight, and that he was quite as able to do his work (he is a sculptor by profession) as he had been before the operation. His only complaint was on account of occasional diarrhœa.* Many other cases of resection of large portions of the ileum have recently been reported, usually with results which were entirely satisfactory.

From all this it would appear that the removal of a large portion of the ileum, for sufficient reasons, is perfectly justifiable; provided, of course,—and here is the danger in resecting large portions of an intestine,—that a sufficient length of intestine is left to carry on nutrition properly. In this connection, it is interesting to observe that the ileum, which, as far as we can now see, is the least valuable part of the small intestine, is far more frequently the seat of pathological lesions than is the jejunum.

THE REAL SHAPE OF THE MESENTERY; DEMONSTRATIONS IN SITU; THE TWO PORTIONS OF THE MESENTERY.

The mesentery is a flat structure, whose root is about 6 inches (15¼ centimetres) long, and whose free border, which extends from one end of this root to the other, averages from 21 to 23 feet (6.40 + metres to 7.01 + metres) in length, while the distance from the base of the mesentery to its free border at any one point is usually not more than 7 inches (18 centimetres). It is clear that a satisfactory demonstration of such a structure *in situ* is not possible by the ordinary methods.

* It occurred to me that perhaps this so-called "diarrhœa" might really be the result of the fact that the loss of so much absorbing surface necessitated the retention on the part of the intestinal contents of more than their usual amount of watery constituents.

FIG. 3.—Showing the intestinal tube thrown into alternate curves, which are held in place by means of a stout copper wire within the gut. The alternating arrangement of the loops is most evident near the lower end of the ileum. The mesentery is flat up to the place where the ruffled edge begins. (Drawn, with slight modifications, from a photograph.)

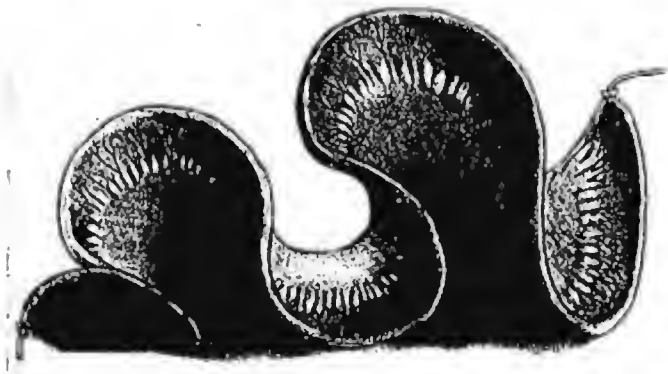


FIG. 4.—Showing *in situ* from above a portion of the intestine with its attached mesentery. It is thrown into large curves, and held there by means of a stout copper wire within the lumen of the gut. (Drawn from the specimen and from a photograph.)

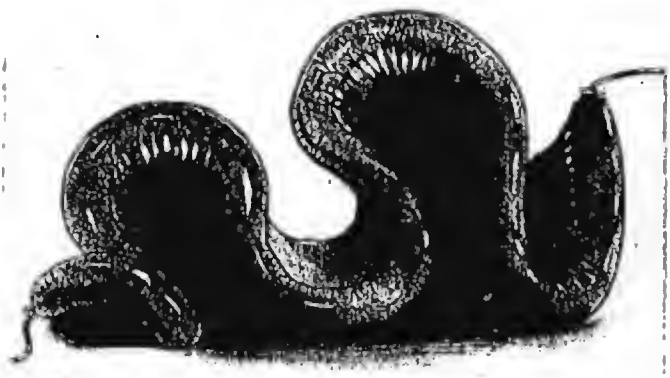


FIG. 5.—The same specimen shown in Fig. 4, with the bowel somewhat inflated.

In my paper on "Intestinal Localization" I tried to simplify its demonstration by introducing a small dowel into the lumen of the gut, about 8 inches (20 centimetres) from the ileocæcal valve, and, after "gathering up" the entire tube on it in the same way that an earthworm is drawn upon a hook, I caused the intestine and mesentery to assume a straight line. This can usually be done on intestines of moderate length and thickness where there is not too much fat in the mesentery.

By means of this contrivance I was able not only to demonstrate the entire mesentery and small intestine, but also, by turning the rod to the left or to the right side of the abdomen, to give an opportunity of inspecting and comparing the right and left fossæ of the abdomen with the greatest ease.

This demonstration, I thought, made the shape of the mesentery somewhat clearer; but still the folds in the distal parts of the mesentery and the gathers in the gut itself made it evident that it would be quite impossible to represent all the parts on the same plane. I therefore devised the scheme of running a stout copper wire through the intestine, bending it into continuous curves, which were made to alternate from one side of the mesentery to the other, in this way "taking up all the slack," as it were. I was able therefore to show simultaneously the whole of the mesentery and the intestine spread out without folds (Fig. 3).

In Fig. 4 another experiment with copper wire within the intestine is shown. Only a portion of the gut is here used. The point of view, being different from that in Fig. 3, gives a rather better idea of the course of the intestine and the attached mesentery. The curves are much longer than those in Fig. 3.

Another illustration (Fig. 5) shows the portion of intestine and mesentery represented in Fig. 4, the bowel having been distended with air.

From these demonstrations, it is quite evident not only that the distance between the two ends of the mesenteric root increases considerably the farther we take our line out on the

mesentery towards the gut, but also that this rate of increase, while gradual at first, suddenly becomes very marked after the ruffled border of the mesentery has been reached. In order to determine roughly, in figures, the rate of this increase, I made some measurements of the relative lengths of the mesenteric root, of the mesentery close to the bowel, and of the mesentery half-way between these points. In order to establish this middle line, I measured the length of a mesentery *in situ* at every foot of the intestine, in the manner already described, determining, however, at each foot of the intestine the point on the mesentery which indicated one-half of the distance between the root of the mesentery and its intestinal border. At each point thus determined I tied a knot of silk and cut off the ends. I then had a line of knots, running from above downward, exactly half-way out on the mesentery. I now measured the mesentery along these knots, proceeding carefully from one to another. I also measured the length of the root of the mesentery, and of the mesentery at its insertion into the bowel. The following are the figures:

Length of mesenteric root, 6 inches (15 centimetres). Length of mesentery half-way between the mesenteric root and the intestinal border, 23 inches (58 centimetres). Length of mesentery at bowel, 13 feet 8 inches (4.16 metres).

Expressed in other terms, which assume the length of the mesenteric root to be one unit, the measurement of the mesentery half-way to the gut was 4 units, and the measurement of the intestinal edge of the mesentery 27 units. These figures give an idea as to the enormous increase in length which takes place in the outer half of the mesentery. It does not require much inspection of the parts to realize that almost all of this great elongation really takes place in the outer one-third or one-fourth of the mesentery, that is, from the beginning of the ruffling of the mesenteric border. The mesentery, therefore, may well be described as consisting of two portions:

(1) *A proximal or flat portion*, comprising that part of the mesentery (about two-thirds or three-fourths of it) which

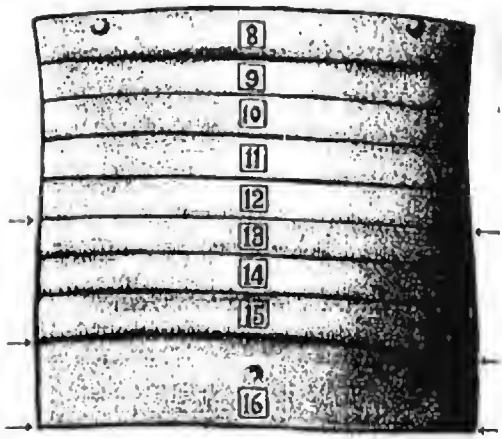


FIG. 6.—Showing *in situ* the sections of the trunk of an adult male. The two nipples and the umbilicus are the only landmarks. Arrows indicate the three sections to which reference is made in the text. (Drawn from a photograph of all the sections *in situ*.)

FIG. 7.—Showing the upper side of section No. 13. The mesentery, indicated here as in the other drawings by a thick white line, sweeps boldly towards the left side of the subject. (Drawn from the specimen.)

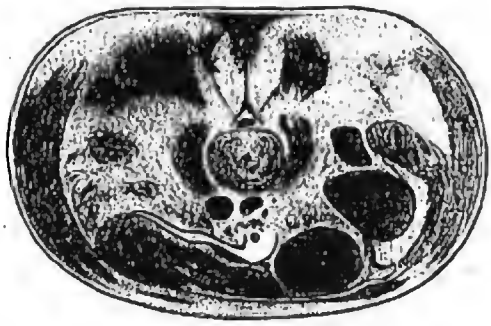


FIG. 8.—Showing the upper side of section No. 16, which is cut slightly out of line. This section is at a level less than an inch above the umbilicus. The main sweep of the mesentery is towards the right side of the subject. Other sections of the mesentery appear at this level, but they are apparently distal portions from that part of the mesentery which rises higher up in the abdomen. (Drawn from the specimen.)

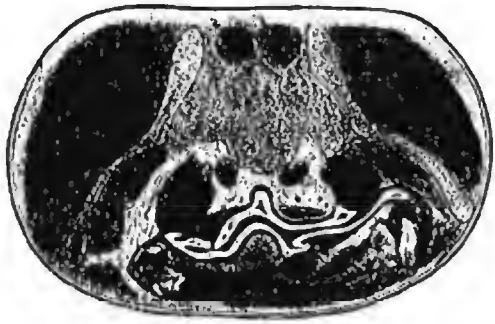


FIG. 9.—Showing the under surface of section No. 16. Because of the fact that below this level the sections were cut vertically and many of the parts had therefore fallen out, the under surface of section No. 16 was reversed so as to correspond with the drawings of the other two sections, and it was therefore assumed that this reversed section represented the upper surface of what would have been section No. 17. had the cutting of horizontal sections down the body been continued. This section is below the level of the lower end of the mesenteric root, which end was easily found on the specimen by opening up the spaces. Several sheets of mesentery are here seen. They are very irregularly disposed and twisted, and, of course, correspond with the coils of ileum which descend into the iliac regions and pelvis. (Drawn reversed, as described above, from the specimen.)

lies between the mesenteric root and the somewhat indefinite line where the ruffled border begins. This line might with propriety be called "the base of the ruffled border of the mesentery."

(2) *A distal portion, or "ruffled border"* (comprising the remaining one-third or one-fourth of the mesentery), which lies between the proximal or flat portion of the mesentery and the intestine.

DISPOSITION OF THE MESENTERY IN THE ABDOMINAL CAVITY.

Inasmuch as the length of the mesentery increases the farther out we remove our line from the mesenteric root, it is evident that, in order to accommodate itself to the restricted space allowed for it in the abdomen, the mesentery must be thrown into curves or folds. These folds must become more and more numerous the farther we remove our line from the mesenteric root. This tendency in the mesentery to assume the shape of curves or folds is repeated in the intestine in a manner which we shall see later. In addition to such investigations as I have been able to make on this subject on the ordinary cadaver, I have, realizing the great difficulty of getting accurate observations, carefully examined in reference to this point a series of frozen sections of a male adult, which belongs to the Anatomical Department of the Harvard Medical School, and, with the kind permission of Dr. Dwight, Professor of Anatomy, have reproduced three of them in which is emphasized the distribution of the deeper parts of the mesentery. Fig. 6 is drawn from a photograph of the body before the sections were taken apart, and Figs. 7, 8, and 9 show three of the sections, these being the only ones in which the mesentery could be distinctly made out. In order to understand these sections, it is best to imagine that the observer stands in front of the trunk, and that he looks down upon each section as those above it are removed.

While these sections belong to only one individual, yet the

evidence which an examination of them furnishes, so far as it goes, is of value, if only to illustrate the tendeney of the mesentery to alternate in its direetion, first to one side of the abdomen and then to the other. It is evident that in this individual the mesentery was first directed to the left, and lower down to the right. Below this its eourse eannot be clearly made out; but the third seetion shows two broad sheets in contact with each other, which extend from one side of the pelvis to the other.

Before leaving this subjeet, I should like to call attention to the fact that, as the sheets of the mesentery in the upper part of the abdomen leave their line of attachment at the mesenterie root in a direction more or less at a right angle with that root, these sheets are apt to be much flatter than those below, which, pursuing a course more or less parallel with the mesenteric root, show a mueh greater tendency to lie in folds.

THE PELVIC FOLD OF THE MESENTERY; HOW TO PALPATE IT; ITS USE AS A LANDMARK.

That part of the mesentery which descends into the pelvis from the lower end of the mesenteric root can usually be felt distinctly by the examining finger. It is somewhat singular that no allusion, so far as I have been able to diseover, is made in surgical literature to the fact that this part of the mesentery can be so easily palpated through a wound in the lower part of the abdomen. I have ventured to give to this fold the name, "the pelvic fold of the mesentery," and I think the fitness of this name will be evident to any one who hooks his forefinger around it. On numerous oecasions I have felt this fold on the cadaver, and not infrequently on the living subject. It seems to me that it is of distinct use as a landmark, for, whenever we wish to enter the great fossa on the left side of the mesentery, we have only to push our finger around it. On at least six occasions I have guided the tip of the irrigating tube around it to the left side of the abdomen,

FIG. 10.—Showing the forefinger rounding the lower end of the ileum to reach the left side of the mesenteric root. The ileum and its mesentery are held up, so that the finger-tip may be seen.

and have thus satisfactorily flushed out that great cavity. The cases in which this was done were cases of general peritonitis following appendicitis. The presence of this "pelvic fold" may also assist the surgeon in finding the lower part of the ileum, a procedure which will be considered in detail under the next heading.

HOW TO FIND THE LOWER END OF THE ILEUM THROUGH AN ABDOMINAL WOUND.

Knowing how important it may be for the operator in cases of suspected typhoid perforation, and in some cases of appendicitis, to find at once and without difficulty the lower end of the ileum just before it enters into the cæcum, I have devised a method which I have frequently used with success, at least on the cadaver. The technique of this procedure consists in carrying the forefinger over the psoas muscle and the iliac vessels, keeping the finger-tip close to the parietal peritoneum, and so entering the pelvis. The finger is then turned on its own axis and hooked upward, the peritoneum at the back part of the pelvis being followed carefully. In this procedure the finger usually goes behind the ileum, entering the cavity on the left side of the mesentery, where the finger comes against the lower end of that structure. The thumb and forefinger then close upon each other, grasping what is between them. When this is brought from among the coils of intestine, it will generally be found that it is a loop of the ileum, quite close to the ileocæcal valve. It is quite easy to do this, and to do it rapidly, in case the last part of the ileum hangs in the pelvis (Fig. 10). When, however, it lies above the ileocæcal valve, which appears to be the rule in about 50 per cent. of all cases, the manipulation just described is not always successful. A little practice on the cadaver, however, will usually enable one to trace out the lowest part of the ileum from its mesentery at the lower end of the mesenteric root.

INFLUENCE OF THE MESENTERY ON THE COURSE OF THE INTESTINE.

It seems to me that the effect of the mesentery as a factor in determining the course of the intestine is hardly recognized as fully as it ought to be. While, as we all know, there are a number of influences which may affect the course of the intestine,—such as peristalsis, pressure from other viscera, distention by gas or other contents, etc.,—yet all these influences apparently have less effect upon the course of the intestine than has the mesentery.

Influence of the mesentery on short segments of intestine; it curves the intestine into a single loop.

That the intestine itself, freed from its mesentery, is straight, or nearly so, is easily proved. We remove from the cadaver a piece of ileum, say a foot or so in length, and carefully take away all the mesentery from it. If we then hold it horizontally between the thumb and fingers of both hands (as shown in Fig. 11), we see that it is quite straight.

If we now remove the mesentery from a corresponding piece of jejunum, and use the same test as that described above, we shall find that this segment of intestine, though not entirely straight, becomes nearly so (Fig. 12).

Now that we have shown the intestine, freed from its mesentery, to be straight, or nearly so, it remains to be demonstrated that it is the mesentery which, when it is attached to the intestine, prevents the latter from assuming a straight line, and obliges it to take a curved course. If a piece of ileum, like that shown in Fig. 11, is removed from the abdomen, with its mesentery still attached, it will be found quite impossible to straighten it on account of the restraining influence of the mesentery which keeps it curved (Fig. 13).

The concavity of the curve in this segment of intestine is on its mesenteric border, and the convexity is on the free border. There are other curves to which the intestinal tube is subject. These will be referred to later.

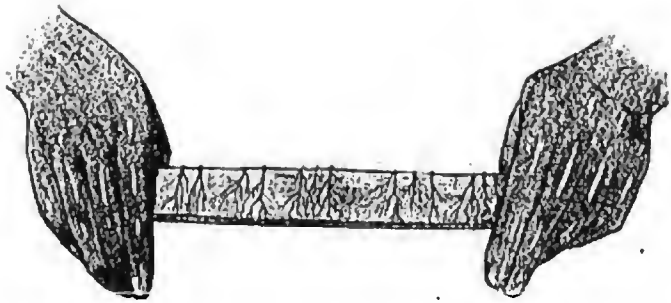


FIG. 11.—Showing a section of ileum from which all the mesentery has been carefully removed. The traction used is only enough to keep the upper line (the mesenteric border) of the gut straight; in other words, just sufficient to overcome the natural sag of that line. The gut is seen to be perfectly straight. (Drawn directly from the specimen.)

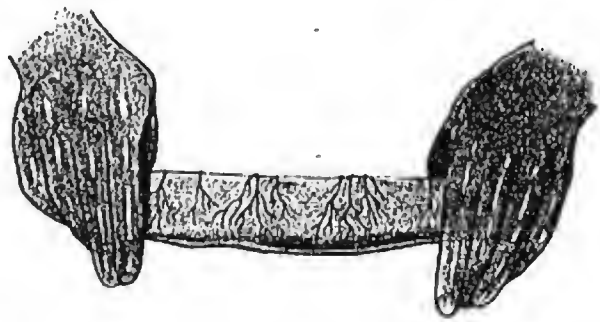


FIG. 12.—Segment of jejunum from the same subject which furnished the specimen shown in Fig. 11. This segment of intestine, though not perfectly straight, is nearly so.

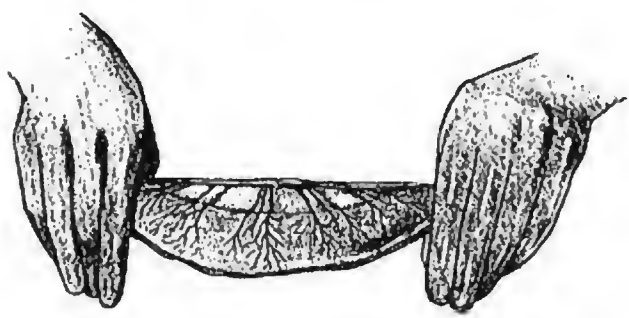
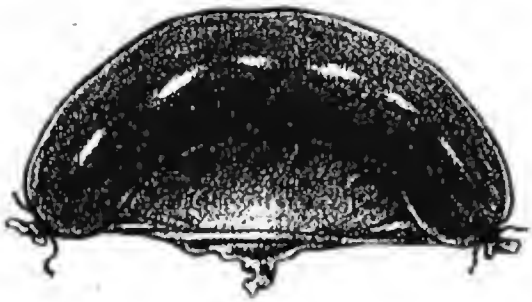


FIG. 13.—Representing the attempt to straighten the same piece of ileum shown in Fig. 11 before its mesentery was removed. The gut cannot be straightened, owing to the restraining influence of the mesentery which keeps it on a curve. The concavity of this curve is on the mesenteric border of the gut, and the convexity on its free border. It is quite obvious from this figure why the length of the entire intestine is so much greater when the measurement is made along its free border than it is when made along its attached or mesenteric border.



a

b

FIG. 14 (a).—Showing a short segment of intestine closed at the ends and distended with air. The V-shaped piece of mesentery is still attached. The gut is strongly curved, and traction lines appear across the mesentery, suggesting a tense bowstring. (Drawn from the specimen.)

FIG. 14 (b).—Representing the same segment of inflated intestine shown in Fig. 14 (a). Section of the mesentery at right angles to the line of traction along its base has caused the intestine to assume a straight course. (Drawn from the specimen.)

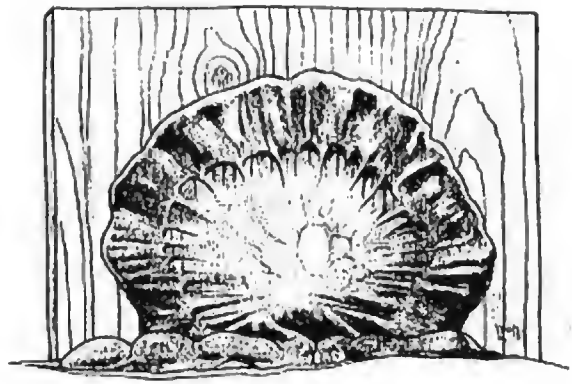


FIG. 15.—Exhibiting a loop of small intestine which has just been drawn out of an abdominal wound. The transverse lines across the base of the mesentery are lines of traction, brought into prominence by the attempt to straighten the tube. The hands drawing the specimen apart at the two sides are omitted intentionally. (Drawn partly from the specimen and partly from a photograph.)

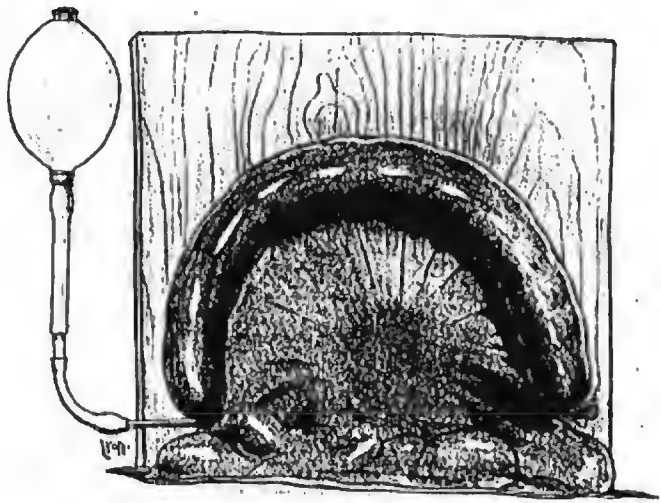


FIG. 16.—Showing distention with air of the same loop as is shown in Fig. 15. The ruffled border of the mesentery is stretched. (Sketched from specimen and from a photograph.)

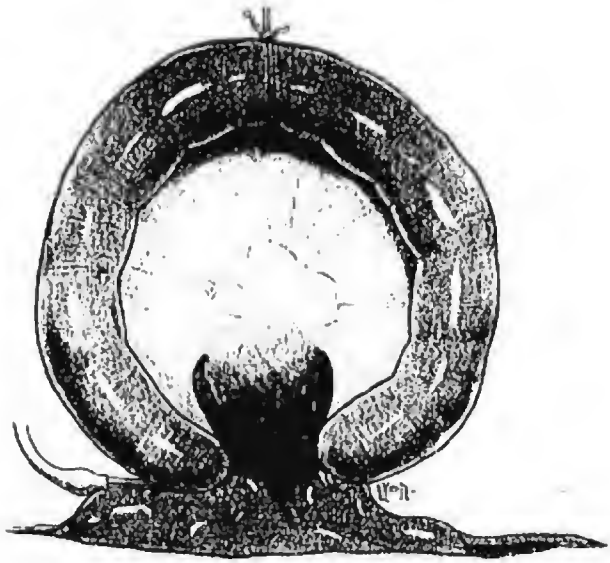


FIG. 17.—Showing the intestine still further inflated with air. The two ends of the loop are closely approximated. That part of the mesentery just inside the loop is stretched, while in the centre is a depression which is continued into a gutter running to the deeper parts of the mesentery.

FIG. 18.—Exhibiting the appearance of the distended loop of bowel and its attached mesentery, shown in Fig. 17, as seen from the rear. That part of the mesentery which is nearest the bowel is tense and flattened, while the rest of the mesentery is continued downward from a point near its centre into the abdominal cavity. (Drawn from the specimen and from a photograph.)

The restraining effect of the mesentery is clearly seen in the following experiment. We tie up the two ends of a small segment, say six inches, of intestine, and then inflate it, the V-shaped piece of mesentery to which it corresponds remaining attached. The result will be that the distended intestine will appear curved like a bow. Traction lines, suggesting the string of the bow, will be seen on the mesentery (Fig. 14, *a*).

Let us now divide the mesentery on a line at right angles to the line of traction. When this is done, the tube instantly assumes a straight course (Fig. 14, *b*).

From this it seems likely that, while the mesentery corresponding to a piece of inflated intestine which is as long as six inches can curve the gut appreciably, the mesentery belonging to one-half of this length of tube cannot prevent the tube from assuming its natural direction, that is, a straight line.

The effect of the mesentery in obliging the bowel to take a curved course is also clearly seen when a somewhat longer loop is drawn from an abdominal wound, and an attempt made to straighten it. This is well shown in Fig. 15. When one inflates this loop with air, its curve becomes somewhat exaggerated (Fig. 16).

When this loop is still further inflated, the ends tend to come nearer together. That part of the mesentery corresponding to the ruffled border is very tense, except on that side which corresponds to the gap between the ends of the bowel, where a loose gutter-shaped depression runs down towards the base of the mesentery. From an inspection of this specimen (Fig. 17), it is evident that the intestine is curved by the tense mesentery, which appears to act on the loop of gut in the same way that tense cords from one part of the gut to another would act.

On lifting up this specimen and suspending it so that the distended loop of bowel is horizontal, and, viewing it from behind, the tense part of the mesentery which lies next the bowel is also horizontal, while the narrow neck of the mesentery reaches downward into the abdominal cavity, and we see

that the whole specimen presents a certain resemblance to a mushroom (Fig. 18).

Although it is not at once evident why the inflation of an intestinal loop causes the mesentery to assume this peculiar shape, yet after a little thought the reason will be clear. The horizontal and tense portion of the mesentery is the elongated "ruffled border of the mesentery," and the comparatively loose and vertical portion belongs to the deep, or proximal, part of the mesentery.

One other noteworthy thing about these inflated loops is a rotation of the bowel on its own axis, which slowly takes place while the air is being injected. The concavity of the curve of the bowel changes to one of the lateral aspects.

Influence of the mesentery on longer segments of the intestine; the bowel is made to assume a serpentine course made up of alternating loops. We have seen that, with the help of stout copper wire within the lumen of the intestine, we can cause the intestine to assume a course made up of alternating curves; but we have not yet determined whether such a course is a natural one on the part of the intestine. We know, of course, because of the shape of the ruffled edge of the mesentery, and also because of the fact that the intestine, at least its free border, is even longer than the intestinal edge of the mesentery, that the intestine must be thrown into coils, but we do not yet know that these coils have a tendency to alternate, first on one side of the mesentery and then on the other. A glance, however, at Fig. 19, which shows this tendency in a collapsed strip of gut hanging from the two ends of its ruffled border (the rest of the mesentery having been removed), and at Fig. 20, which shows this tendency still more marked when the same piece of gut is inflated, will be fair proof that such is the case.

For the next experiment a piece of bowel about two feet long was isolated by placing a ligature around each end of it. This isolated bowel was then inflated, when at once it sprang to the front and stretched its mesentery, assuming the shape of a figure of 8 (Fig. 21).

FIG. 19.—Showing a portion of the jejuno-ileum from which all the mesentery has been removed except the adjacent strip, about two inches in width, from the two ends of which the tube is suspended. This strip of mesentery includes nearly all, if not all, of the ruffled border. The different segments of the intestine tend of themselves to hang alternately on the two sides of the mesentery.

FIG. 20.—Showing the same specimen inflated. The alternation of the loops is still further emphasized. These loops spring laterally from below the cut line of the mesentery, and tend to encircle it. Another curve, reaching from side to side, and with its convexity downward, is evident along the whole length of the specimen.

FIG. 21.—Showing the figure-of-8 shape assumed by a two-foot piece of intestine when it is inflated *in situ*.

FIG. 22.—Showing the alternating curves assumed by an intestine when it is inflated, when the mesentery along the base of its ruffled edge is held rigidly in a straight line.

FIG. 23.—Showing a specimen of recently removed intestine and mesentery, suspended from the root of the latter, which has been nailed to a board. The whole is held in a position nearly vertical. The mass has somewhat the same relation to the mesenteric root that it would have in life if the subject was in the erect position. The alternation of the loops is evident, especially in the upper part of the specimen.

It was evident from these experiments that, while inflation of a short loop of bowel would cause such a loop to assume a single curve, inflation of a longer piece would result in figure-of-8 or sigmoid curves, and that inflation of a still longer piece would cause the bowel to assume a serpentine course, made up of a series of loops, alternating first to one side and then to the other.

In the next experiment a long piece of bowel, and a strip of its adjacent mesentery about 2 to 2½ inches in depth, were used. This mesenteric strip, which roughly represented the ruffled border of the mesentery, was nailed along its proximal edge in a straight line to a board. The ends of the gut were then tied up and the tube inflated. The result was what might have been expected, for, on inflation, a fairly regular series of alternating curves formed, the mesentery assuming a corresponding shape (Fig. 22).

It should, of course, be borne in mind that in the abdomen the base of the ruffled border is not straight, as represented in Fig. 22, but that it is more or less serpentine in its course. This, of course, makes the arrangement of the coils of intestine as they exist within the abdomen still more complicated than it would be if this base were straight.

With the idea of simulating even more closely than in the last experiment the conditions within the abdomen, a specimen comprising the small intestine and its entire mesentery was experimented upon. The mesenteric root of the specimen was nailed in a straight line to a board, and the board held in a position nearly vertical. On examining this specimen, especially the upper part of it, we see that the natural folds of the mesentery end in corresponding folds in the gut, the alternating arrangement of the latter being evident (Fig. 23).

We now inflate the bowel in this specimen, and such great irregularities appear in the distended coils that at first no definite arrangement is recognizable (Fig. 24). We see, however, that there are many loops of different shapes and sizes, whose planes differ considerably in reference to one another,

and on careful inspection we recognize here and there a sigmoid curve. From what we have learned in the preceding experiments, I think we are justified in considering that each loop represents a part of the alternating arrangement of loops already referred to, the compensating loop, if not on the surface and open to view, being hidden in the intestinal mass; and also that each sigmoid curve of the intestine represents the connecting link between two such loops. The curving of the intestine during inflation, combined with the crowding of the distended coils upon one another, was very marked in this experiment. When the intestine was fully dilated, the mass of coils reached so far around the sides and back of the board on which the specimen was mounted as to nearly encircle it.

Kinks in the intestine. Whenever my attention has been called to the existence of kinks in any part of the intestinal tube, I have noticed that these kinks are almost invariably *on the lateral aspect of the gut*, that they are seldom on the mesenteric border, and only in the rarest instances on the free border. There are several examples to be seen in Fig. 24. Kinks are simply exaggerated instances of sharp curves, and are caused, at least when the gut is distended, principally by the restraining effect of the mesentery, which obliges the intestine at these points to double sharply on itself. The pressure exerted by the other coils in the neighborhood probably assists to some extent in the formation of these kinks.

COURSE OF THE INTESTINE AS AFFECTED BY CONDITIONS WITHIN THE ABDOMEN.

When the intestines are within the abdominal cavity, the conditions are so different from those we have been considering that it is not surprising to find the regularity in the disposition of coils considerably interfered with. New factors, such as pressure from other viscera, or from one coil on another, or from unequal weight because of distention by gas or fluid intestinal contents, or from peristalsis, or from the changing position of the body, add very disturbing elements to the regu-

FIG. 24.—Showing the effect of inflation on the intestine seen in Fig. 23. The specimen is still held to the board by the root of the mesentery. The various loops of intestine, some of which appear in well-rounded curves or in kinks, while others take a sigmoid course, presumably form parts of the alternating arrangement of loops to which reference is made in the text.

FIG. 25.—Exhibiting the wide open abdomen, in which the coils of small intestine, having been moderately distended with air, have sprung to the front. Large loops of different curves and a few kinks are seen. Presumably, the compensating loops are mostly buried in the mass of intestine. One sigmoid curve is evident in the left lower corner of the drawing. (Drawn from the subject.)

larity of the alternating curves. Some of the curves may be longer and some shorter than most of those which we have thus far been considering, and their planes may be greatly altered in reference to one another, one curve being in the front of the abdomen, and the next in the middle or back of it; but, by careful examination, evidence of some such alternating arrangement as we have spoken of can generally be made out, *if we look far enough;* for I hold it to be impossible, on account of the arrangement of the ruffled border of the mesentery, to which is attached an intestine longer than itself, that a segment of intestine can proceed for any appreciable distance on one side of the mesentery without crossing to the other side to form a compensating curve. In Fig. 25 the entire small intestine is shown inflated *in situ*. Most of the loops are large ones. There are a few kinks. The compensating loops are presumably beneath the other coils. One sigmoid curve appears.

CONCERNING DISTENTION OF THE INTESTINES; EXPERIMENTS IN THE INTRODUCTION AND REMOVAL OF AIR AND WATER.

I have often noticed that when in operations an enterostomy is done to relieve a gut distended with gas and liquid contents, usually little gas or other contents escapes at the time of operation, and that, therefore, the abdominal distention is not reduced to any great degree. I have therefore opened a number of gas-distended coils on the cadaver, to find that in every case the collapse of the gut which followed the escape of the gas was a purely local one, only a coil or two emptying its contents, while the rest of the intestine remained as much distended as before. It was obvious, therefore, that there was some obstruction to the escape of the gas from the other coils of intestine, and I came to the conclusion that the small intestine consisted presumably of various segments, not always opening freely into one another, which segments acted as separate reservoirs for gas or other contents, and that the

collapse by emptying of one of them did not necessarily mean the emptying of the others, at least, not their immediate emptying. These remarks refer, of course, to the dead intestine, or to the living one which is completely paralyzed.

In order to study this matter a little farther, I conducted a number of experiments by inflating the gut on cadavers. All these experiments were performed with the abdomen fully laid open. First, I inflated the whole tube by the use of a hand bulb, forcing air through a cannula into the intestine. The effect was what might have been expected, for the loop nearest the cannula would slowly become distended, and, as it did so, it would spring up from its bed, at the same time putting its mesentery on the stretch. At this point it was noticed that it was harder to inject air into the gut than had been the case at first; in other words, one seemed to be working against a slight obstacle. This obstacle would suddenly give way, and the inflation process would go on smoothly for a time until another obstacle was met, which in its turn would also give way; and so on, one chamber after another being opened up until the entire gut was fully inflated, when usually air could be forced from one end to the other. During all this, with each new reservoir opened up, the loop into which the air was entering would spring to the front and stretch its mesentery. When the whole tube was fully inflated, an incision into any coil would be followed by a gradual subsidence of apparently all the coils. This would take place up to a certain point, when the general collapse would be arrested, and the complete collapse of the coils nearest the opening follow, the other coils still remaining somewhat distended. Obviously, the pressure remaining within the distended coils was not sufficient to force out all the air which had been injected. Gentle pressure on the distended coils had the effect of forcing out more air, and massage was still more effective; but it was next to impossible to remove all the air without actually "stripping" the intestinal tube throughout its whole extent.

Some injections were tried with water and some with

water and air, but they demonstrated little beyond what one would expect; that is, that the water sank to the most dependent parts of coils, the air remaining in the uppermost parts. It was interesting, however, to note that when a distended loop on the front of the abdomen (the subject lying on his back at the time) was punctured, air escaped, but no water, and that on opening one of the most dependent loops water escaped, but usually little air. This water in the dependent loops evidently acted as a most efficient trap, like a plumber's trap, separating the different segments of the intestine; and, inasmuch as no single coil can continue along the anterior abdominal wall for any distance without taking a course near the back, it follows that wherever there is fluid enough in the intestines there must be traps which shut off the different compartments of the small intestine from one another. It is quite possible, in intestines filled, as in peritonitis, with gas and semiliquid contents, that the gas is in the loops nearest the abdominal wall, the fluid being posterior in the dependent loops. If this is the condition of things, it is evident that opening the gut, or, in other words, doing an ordinary enterostomy, will not be followed by an immediate discharge of all the contents or a collapse of the bowel, but that it will be necessary to wait for a certain amount of peristalsis to drive the intestinal contents downward. In addition to the obstacles presented by these traps in the most dependent loops, there are, of course, other obstacles, for semisolid contents may act as such, or obstructive kinks may be present in the intestine. Apparently also the weight of the intestinal mass may press the sides of the gut so firmly together that even the pressure within the adjacent distended gut is not sufficient to open up the tube and allow the gas to pass on.

A few experiments were made with the idea of determining whether it was possible, by suction through a tube tied into the gut, to empty an appreciable length of the intestine. The results were very unsatisfactory, as the experiments showed that very little fluid or air could be withdrawn from the

intestine in this way. Equally unsatisfactory was the result of an attempt to irrigate from one end of the intestine to the other. This was tried only once, the abdominal contents being *in situ*, and the median wound in the abdominal wall being united over them. The greatest eare was taken to inject the water slowly and gently. The result of the experiment was, as might have been expeeted, to show that sueh irrigation would be quite impossible on the living subjeet, for in the experiment the intestine ruptured and the fluid escaped into the peritoneum.*

THE PASSING OF INSTRUMENTS INTO AN ENTEROSTOMY OPENING.

While the passage of a tube into an enterostomy opening in the gut may allow the escape of a considerable quantity of intestinal contents, beyond that which has escaped from the hole itself before the tube was inserted, and while this quantity may be somewhat increased by gentle massage of the abdomen or by flushing, it is hardly possible, on account of the tortuous course of the tube, to pass any instrument, hard or soft, straight or curved, for any appreciable distance either upward or downward, without the probability of very soon engaging a sharp curve or kink in the gut. Before, however, the tip of an instrument reaches a kink, or even a sharp curve, it is very likely to engage the wall of the gut, usually its free border (Fig. 26). This I have repeatedly

* During these experiments, the attempt was made on two or three occasions, when the gut was fully inflated, to rupture it by what has been called "blunt violence." It was thought possible that distended intestines might rupture under a blow, just as an inflated paper bag ruptures under it, and that, if so, this fact might explain how the bowel may be ruptured, without apparent injury to the abdominal wall, by the application of blunt violence. Though the results of these experiments were entirely negative,—for in no case did a rupture take place,—yet the experiments were too few to justify any definite statement as to the possibility of a rupture occurring in this way. It is quite possible, also, that the cadaver is not suitable for experiments of this kind.

FIG. 26.—Showing how soon a straight instrument passed into the gut may engage its free border.

proved on the cadaver, with different kinds of tubes, both hard and soft, when the gut was collapsed as well as when it was inflated.

A number of experiments were made to determine what length of intestine could be "gathered up" on a tube when the instrument was passed through an abdominal wound of the ordinary length, and also through an opening into the gut such as is made in most enterostomies. The tube best suited for this purpose was found to be a glass one with a curved extremity, the opening being on the concavity of the curve. The circumference of the tube was about half again as large as an ordinary lead-pencil. The largest size Coudé catheter answered the purpose nearly as well. The results, however, were not encouraging, for, while it was found that such a tube could be made to penetrate much farther in either direction than any of the soft tubes, it could not take up much more than three or four feet of the intestine, for the reason that the intestine could not be pulled farther out of the abdomen without undue traction on the coils within. Before leaving this subject, however, it should be said that if the wound in the abdominal wall can be made long enough, and if the tube itself is also of sufficient length, the greater part of the gut may be gathered up on the tube.

CONCERNING THE DETERMINATION OF THE REAL DIRECTION OF THE BOWEL IN A LOOP OF INTESTINE.

In connection with the work on intestinal localization already referred to, another study was made, also on cadavers, for the purpose of determining through an abdominal wound which was the proximal end of an intestinal loop, and which the distal. The method by which this determination was made was by following down the mesentery on one side of the gut as far as the mesenteric root. On cadavers the tests resulted in a large proportion of successes; and on the living subject, where I have been able to apply it in a certain number of cases, I have made, as far as I know, no errors. In

ease twists of the mesentery are felt or seen, one should be careful to rotate the loop in such a manner as to untwist these and cause the intestine to run in the same direction as the base of the mesentery, when the mesentery, now parallel with its line of attachment, can be followed down to its base by the finger, and, in ease the coils in the neighborhood are strongly retracted, by the eye. Failures, indeed, are possible; as, *e.g.*, when the wound is so far away from the mesenteric root that the latter cannot be reached with the finger,* or where complicated twists or extensive pathological processes prevent a proper manipulation or view of the root of the mesentery. Since first writing on this subject, I have been impressed with the obvious advantage of examining the mesentery on both sides instead of only on one side, the findings on the one side being verified or disproved by those on the other. In fact, on several occasions, I have been able to grasp the mesenteric root of the cadaver between the thumb and fingers of one hand, thus enabling me to determine the direction of the bowel with certainty. It is quite possible that this method may be of use on the living subject when the wound is large enough, and when a knowledge of the real direction of the gut will be of sufficient value to justify the manipulation.† The method of procedure is as follows:

The loop of intestine is gently lifted from the abdominal cavity, and the assistant grasps its two extremities and holds

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* Though this method for determining the direction of the tube in any loop presenting was, I at first thought, original with me, I later found, as I stated in my article, reference to the method in Woolsey's "Surgical Anatomy" (1902); and, after the publication of my paper, I learned that it had been also spoken of in Stimson's "Operative Surgery" (1895), and in a short article in the London Lancet (December 22, 1883), by Mr. Rand. This last is the earliest reference to the subject which I have been able to find.

† Since writing the above, I have been able in an operation on the living subject to correctly determine the direction of a loop of bowel by this method.

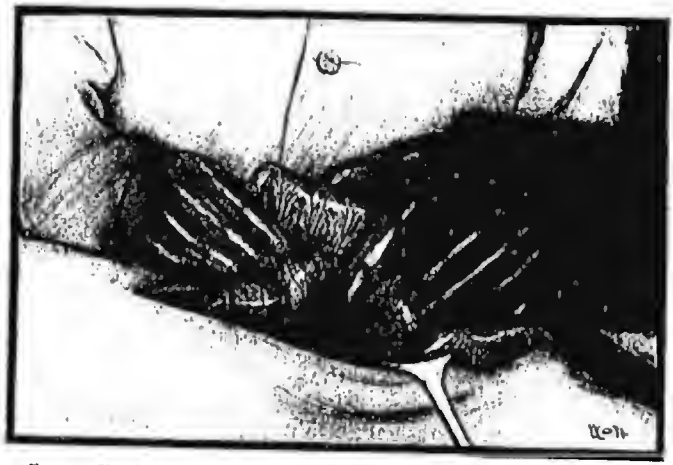

FIG. 27.—Showing the method of determining the real direction of the gut by passing the thumb down on one side of the mesentery, and the fore- and middle fingers down on the other, in the direction of the mesenteric root.

it suspended horizontally. The surgeon, putting his thumb on one side of the mesentery and his first two fingers on the other, insinuates them slowly down towards the root of the mesentery, the slack of the mesentery being taken up by his other hand and by the hands of his assistant (Fig. 27).

By this method, which requires a little practice, the examiner can instantly determine, and this usually before he reaches the mesenteric root, whether or not there is a twist in the mesentery. If there is a twist, it should be untwisted by rotating the loop of bowel, and the mesentery again examined. When there is no twist of the mesentery, and the loop lies parallel with the mesenteric root, the upper end is the proximal end of the loop and the lower end the distal.*

CONCLUSIONS.

Such is the nature of this paper that it does not admit of a satisfactory summary of all the points which have been spoken of in it. As, however, there are certain features which I particularly wish to emphasize, I put these in the form of conclusions. I have attempted to show:

1. That the relative shape of the mesentery and intestine *in situ* can be best understood by arranging the intestine in a series of alternating curves upon a wire, thus putting all parts of the intestine and mesentery gently on the stretch.

2. That the mesentery may be roughly divided into two portions: (1) a proximal or flat portion, which comprises

* A short time ago it occurred to me that, on the living subject, it might be possible to determine the direction of the bowel by the direction of the wave of impulse in the main branches of the superior mesenteric artery near the mesenteric root, it being, however, first made certain that there is no twist in the mesentery between the artery and the gut. This I have tried with success a few times on the cadaver, the impulse in the arteries being simulated by the rhythmical inflation of the vessels with air. I mention this method, however, only incidentally. Whether it can ever be made of practical value, I do not know. The only advantage it has over the methods already spoken of is that, in carrying out the test, it is not usually necessary to go as far as the mesenteric root, since the main arterial branches are often at some little distance from it.

about two-thirds or three-fourths of the mesentery; and (2) a distal or ruffled portion, the "ruffled border," which comprises the remaining one-third or one-fourth.

3. That the main sheets of the mesentery alternate from above downward, going first to the left, then to the right, and finally proceeding to the iliac regions and pelvis.*

4. That the fold of mesentery which descends into the pelvis can usually be palpated from a wound in the lower abdomen, and that it forms a valuable guide for the finger in the attempt to reach the left abdominal fossa. (I would make the suggestion that this fold be known as "the pelvic fold of the mesentery.")

5. That the part of the ileum which is about to enter the cæcum can usually be picked up from a right iliac wound by the forefinger, which, after passing into the pelvis, is curved upward around "the pelvic fold of the mesentery."

6. That while the intestine freed from its mesentery is straight, or nearly so, the mesentery when attached to it obliges it to follow a curved and tortuous course.

7. That, when the gut is attached to the mesentery, the free border of the gut is several feet longer than its mesenteric border, and that the free border may therefore properly be called "the long side," and the mesenteric border "the short side," of the intestine.

8. That the influence of the mesentery is such that the intestine is thrown into a series of alternating loops of varying shapes, sizes, and planes.

9. That kinks in the intestine are usually confined to the lateral aspect of the gut.

10. That a distended and paralyzed intestine, filled with gas or semiliquid contents, does not at once empty itself through an enterostomy wound. That the cause of this is obstruction, not only from sharp curves and kinks, but also from outside pressure on the tube, and still further because

* This roughly agrees with Mall's findings as to the arrangement of the different coils of intestine.

the fluid portions are in the dependent loops, where they act as traps to obstruct the passage of gases along the tube.

11. That, unless the intestine be "gathered up" on the tube, it is impossible to pass any instrument, hard or soft, straight or curved, into the gut without the probability of soon engaging the wall of the intestine, usually in its free border.

And, finally (12), that, when the size of the wound and its situation will permit, the surest method, at least on the cadaver, of determining which is the proximal and which the distal end of a loop of intestine is by palpation of the mesenteric root between the thumb and fingers of one hand.